ECE 331 - Homework #11

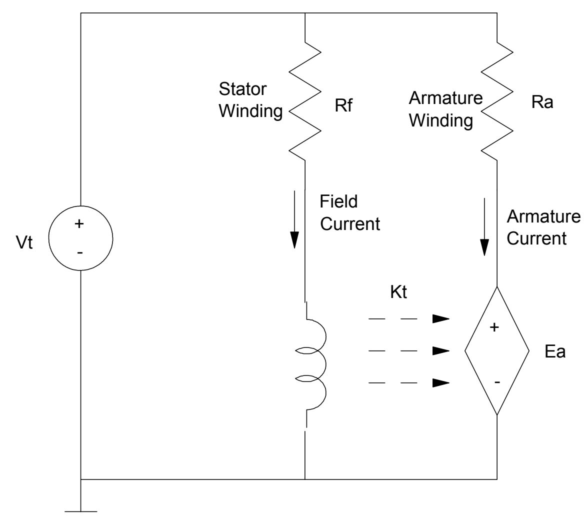
DC Shunt Motors - Due Monday, April 28th, 4PM

1) Assume a DC motor with Vt = 120VDC, Rf = 150 Ohms, Ra = 3 Ohm, Nf = 30, Na = 30, and a reluctance of 1000. Plot the speed vs. load torque relationship. Note: The torque constant is related to the current If:

$$I_f = \frac{120V}{150\Omega} = 0.8A$$

$$\Phi_P = \frac{N_f I_f}{Rel} = \frac{(30)(0.8A)}{1000} = 0.024Wb$$

$$\boxed{K_t = \frac{2N_a\Phi_p}{\pi} = 0.4584\frac{Nm}{A}}$$



Max speed (no load) is

$$\omega_{max} = \frac{120V}{0.4584\frac{Vs}{rad}} = 261.8\frac{rad}{sec}$$

The back-EMF is

$$E_a = K_t\omega$$

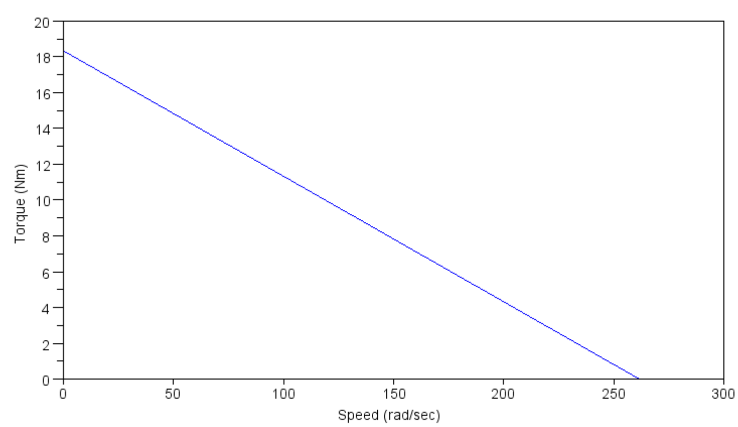
The torque is then

$$I_a = \frac{V_t - E_a}{R_a}$$

$$T = K_t I_a$$

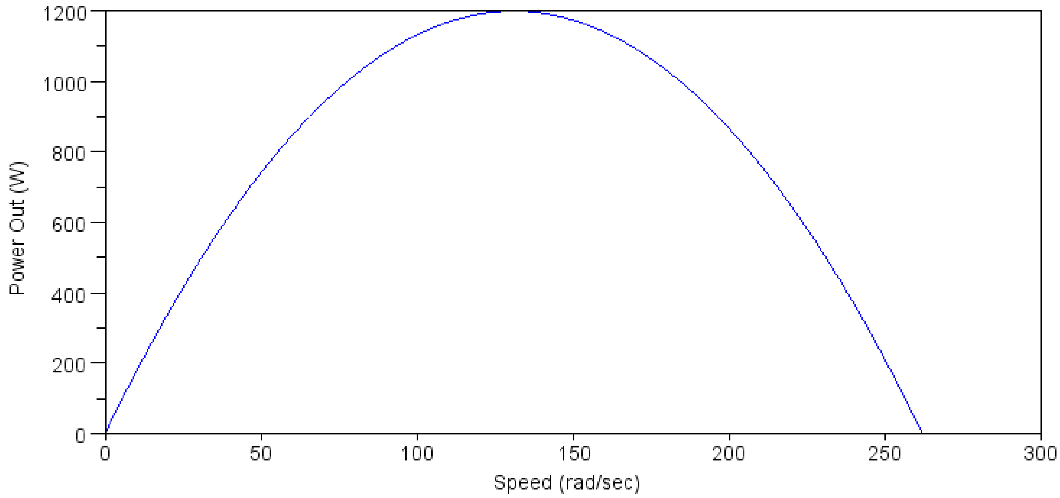
Using SciLab:

```
-->Ra = 3;
-->Vt = 120;
-->Kt = 0.4584;

-->Tmax = (Vt / Ra) * Kt

    18.336

-->T = [0:0.01:1]' * Tmax;

-->Ia = T / Kt;
-->Ea = 120 - Ia*Ra;
-->w = Ea/Kt;

-->plot(T,w)
-->xlabel('Torque (Nm)');
-->plot(w,T)

-->xlabel('Speed (rad/sec)');
-->ylabel('Torque (Nm)');
```



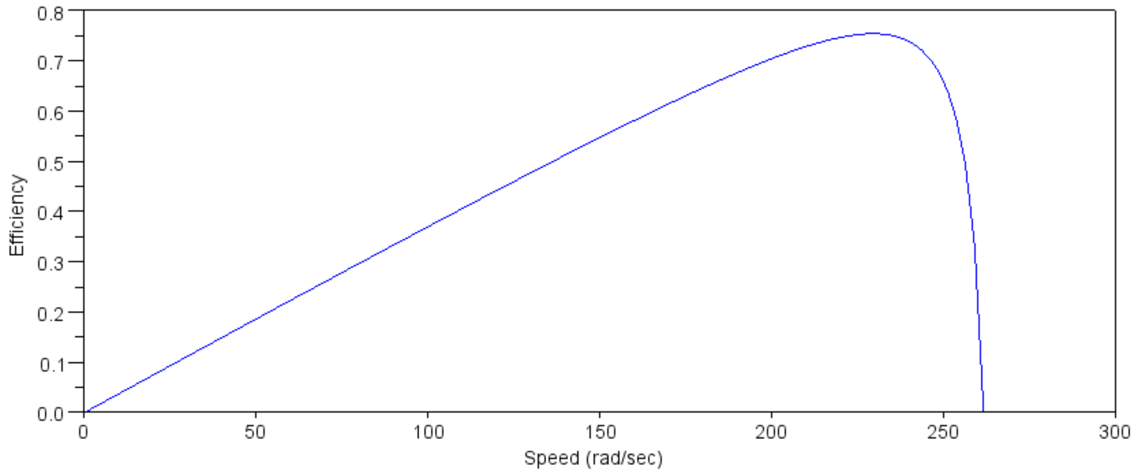
2) For the motor in problem #1, plot Speed vs. power out

```
-->Pout = Ea .* Ia;
-->plot(w,Pout)
-->xlabel('Speed (rad/sec)');
-->ylabel('Power Out (W)');
```



Speed vs. efficiency

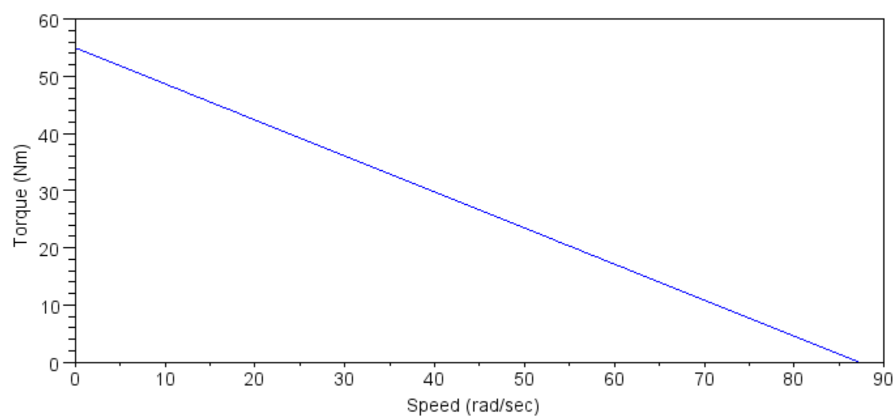
```
-->Iin = Ia + 0.8;
-->Pin = 120 * Iin;
-->Eff = Pout ./ Pin;

-->plot(w,Eff)
-->xlabel('Speed (rad/sec)');
-->ylabel('Efficiency')
```



3) Increase the field current by 3x (reduce Rf to 50 Ohms). Plot

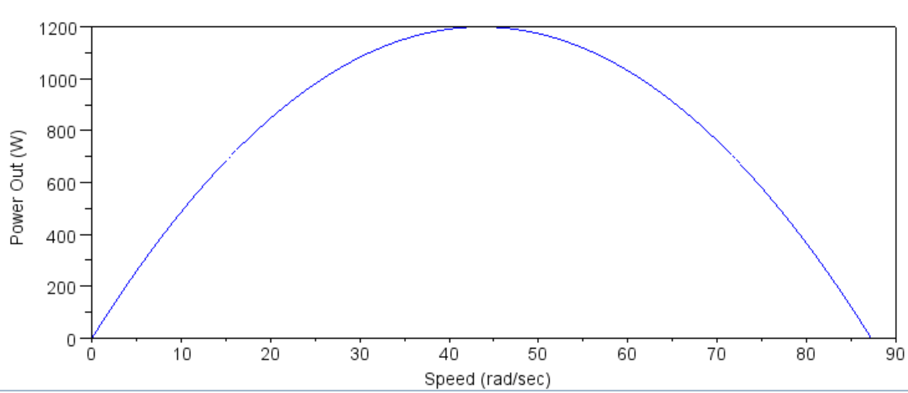
Load torque vs. speed

```
-->Kt = 0.4584 * 3;
-->Wmax = Vt / Kt

    87.260035

-->w = [0:0.001:1]' * Wmax;
-->Ea = Kt*w;
-->Ia = (120 - Ea) / Ra;
-->T = Kt * Ia;

-->plot(w,T);
-->xlabel('Speed (rad/sec)');
-->ylabel('Torque (Nm)');
```



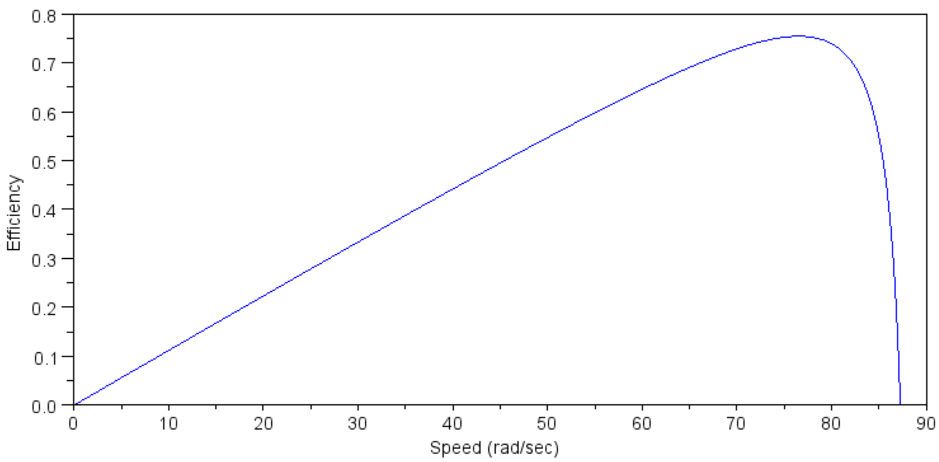
Speed vs. power out

```
-->Pout = Ia .* Ea;
-->plot(w,Pout)
-->xlabel('Speed (rad/sec)');
-->ylabel('Power Out (W)');
```



Speed vs. efficiency

```
-->Iin = Ia + 0.8;
-->Pin = 120 * Iin;
-->Eff = Pout ./ Pin;

-->plot(w,Eff)
-->xlabel('Speed (rad/sec)');
-->ylabel('Efficiency')
```



4) Design a DC shunt excited motor. The motor is to produce 15kW with Vt = 120VDC at 3000 rpm. Specify Rf, Rx, Kt.

15kW @ 3000 rpm means

$$\omega = 314\frac{rad}{\sec}$$

$$T = \frac{15kW}{314 rad/\sec} = 47.74Nm$$

Note: There are many solutions. One solution is as follows:

Let's make the armature of the motor 90% efficient at this speed, meaning Ea = 9*IaRx

$$E_a = 0.9 \cdot V_t = 108V$$

The torque constant is then

$$K_t = \frac{E_a}{\omega} = 0.3493$$

The armature current is

$$I_a = \frac{T}{K_t} = \frac{47.74Nm}{0.3493\frac{Nm}{A}} = 138.81A$$

The armature resistance is then

$$R_a = \frac{120V - 108V}{138.81A} = 0.0864\Omega$$

To get this value of Kt, let's modify the motor from problem #1:

$$K_t = \frac{2N_a\Phi_P}{\pi} = 0.4584\frac{Nm}{A}$$

$$\Phi_P = \frac{N_f I_f}{Rel} = \frac{(30)(0.8A)}{1000} = 0.024Wb$$

$$I_f = \frac{120V}{150\Omega} = 0.8A$$

To change the torque constant to 0.3493, change the the field current

$$I_f = \left(\frac{0.3593}{0.4584}\right)0.8A = 0.6271A$$

Adjust Rf to get the desired current

$$R_f = \frac{‘10V}{0.6271A} = 191\Omega$$

So, the design is similar to problem #1 with the following changes (noted in bold)

- Vt = 120VDC,
- **Rf = 191 Ohms,** (was 150)
- **Rx = 0.0864 Ohms** (was 3 Ohms)
- Nf = 30, Na = 30, and
- Reluctance of 1000.

5) Determine the efficiency of the DC motor you designed for problem #4 at this operating condition.

Pout

Pout = 15kW

Pin:

Iin = If + Ix = $\left(\frac{120V}{191\Omega}\right) + 138.81A$

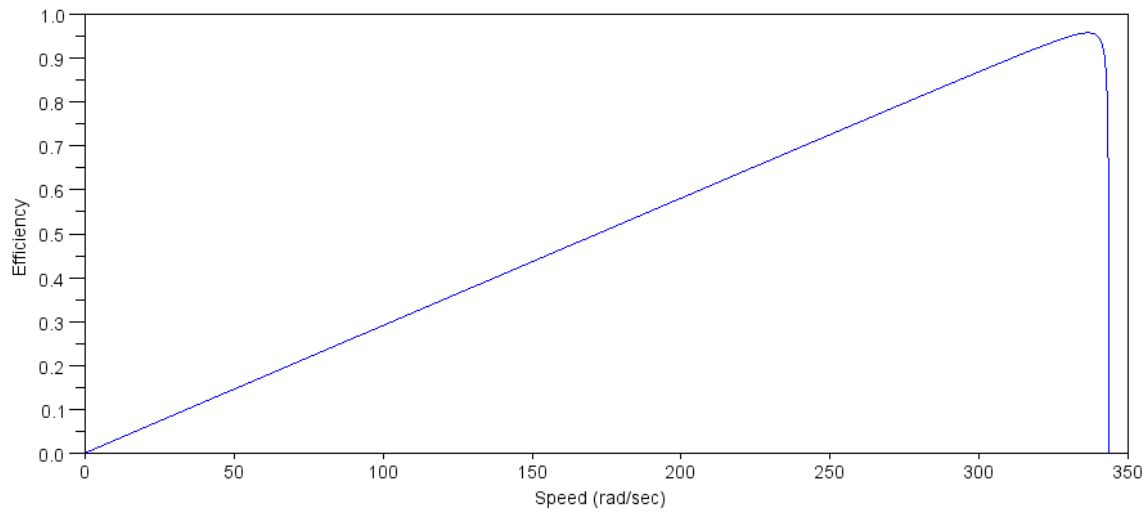
Iin = 139.44A

Pin = 120 * Iin = 16.732W

eff = Pout / Pin = 89.65%

Plotting it just for fun (not required)

```
-->Kt = 0.3493;

-->Ra = 0.0864;

-->Rf = 191;

-->Wmax = 120 / Kt
 Wmax  =

    343.54423

-->w = [0:0.001:1]' * Wmax;
-->Ea = Kt*w;
-->Ia = (120 - Ea) / Ra;

-->Pout = Ia .* Ea;
-->Pin = 120 * Iin;

-->Eff = Pout ./ Pin;

-->plot(w,Eff)
-->xlabel('Speed (rad/sec)');
-->ylabel('Efficiency')
```




```
-->plot(Pout/1000,Eff)
-->xlabel('Power Out (kW)');
-->ylabel('Efficiency')
```